# Efficiency Improvement of an Integrated Giant Freshwater-White Prawn Farming in Thailand Using a Wireless Sensor Network

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***Abstract*—Most local freshwater prawn farmers in Thailand are currently relying their prawn production on a traditional farming approach, which requires highly-experienced farm manager, effort and time. By continuing with this inefficient approach, it is hard to improve the productivity, due to two main difficulties: (1) the difficulty in consistently maintaining the quality of pond water and (2) the difficulty in managing the farm system in a cost effective way. In order to improve the efficiency in aquaculture, many previous works suggest the use of wireless sensor technology in maintaining and controlling the quality of pond water as well as in promoting the efficient farm management. However, with its initially high investment, the deployment of such system has not gained much popularity among Thai prawn farmers.**

**Unlike other previous works that mainly focus on the design of a smart aquaculture system without clarifying how much productivity can really be gained from adopting such system, this study aims to investigate the significance of efficiency improvement obtained from adopting wireless sensor technology (or smart farming) over the use of a traditional approach in an integrated giant freshwater-white prawn culture in Thailand environment. Experimental results reveal that with smart prawn farming approach, significant efficiency gain can be achieved from the ability to extend the culture period significantly by 20.3%, leading to larger-size prawns and more than 150% better in profit, when compare with using the traditional approach.**

## I. Introduction

The majority of freshwater prawn farmings in Thailand are integrated giant freshwater-white prawn farmings which geographically lie in Nakhon Pathom province and its nearby vicinities. Most of prawn farmers are currently using a traditional approach in culturing their prawns, leading to an inefficient farming (in terms of both the quantity and the quality of the produced prawns). Consequently, the amount of production/hector is relatively lower than the one achieved by the farms that utilizes a more advanced and more efficient approach.

In aquaculture, pond water quality is one of the most significant factor in determining the health and the growth rate of aquatic animal [1]. However, for prawn farms in Thailand, there are inadequate scientific means in performing water quality measurement and limited in number of paddle wheel aerators for controlling water quality. Instead of using water quality measurement test kits to measure the level of dissolved oxygen (DO), pH and temperature, the farmers normally use the color of pond water to indicate the water quality. Although this method may work for highly experienced farmers but it is not an efficient way of doing water quality measurement. Also, this way of performing a water quality estimation can only be carried out only twice or three times a day when the farmer approaches the pond for feeding purpose. This implies that even if water quality estimation was always accurate, real-time monitoring could not easily be achieved using this method. This is because real-time water quality monitoring with the traditional approach highly consumes time and man power. Moreover, it is hardly possible to perform water quality estimation at night time during which is the highest Oxygen consumption period within a day. Thus, farmers have no other choices but activating an aerator every night between 21.00-06.30, in order to avoid the lack of DO which can be hazardous to prawns. Activating an aerator base on time of the day is inefficient since the operation of an aerator is necessary only when DO drops below 4 ppm [2]. Usually, this happens more often in night time during which there is no Oxygen produced by photosynthesis from aquatic plant. However at when exactly this to happen is highly complex to unpredictable (to the farmers). This is why farmers have to turn an aerator on for the whole night even though it is highly costly in terms of electrical consumption.

In addition to the difficulty of maintaining the quality of pond water, the way in feeding have a strong relation with the productivity. In order to achieve the best growth rate, it is better to feed more often but with smaller amount at each feed [2]. Unfortunately, this is hard to achieve with manual feeding system that is widely applied by Thai farmers. Thus, the farmers end up feeding at the maximum of twice or three times daily. By feeding with a large portion of food at each feed, there is a high probability that there will be a left over portion of food which can degrade the quality of pond water and food wastage.

As discussed above, there are two major difficulties causing inefficiency in prawn culture in Thailand: (1) the difficulty in consistently maintaining the quality of pond water and (2) the difficulty in managing the farm system in a cost effective

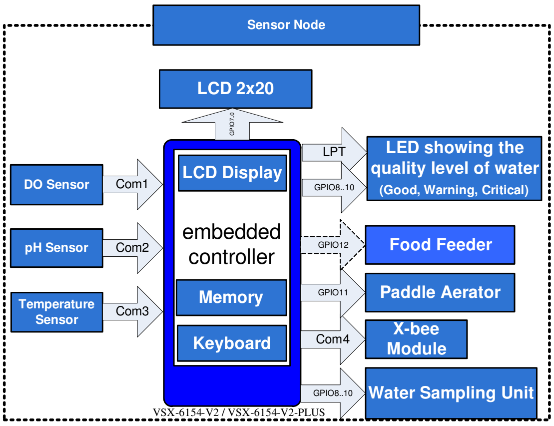



Fig. 1. Design of interfaces between sensor node and other units.

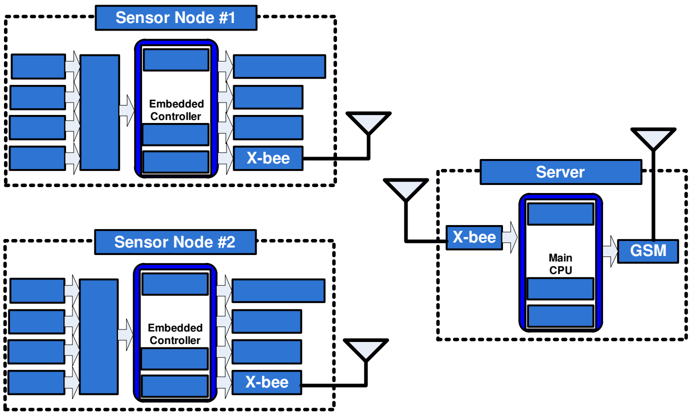



Fig. 2. Sensor network for prawn farming.

way. In order to improve the efficiency in aquaculture, many previous works suggest the use of wireless sensor technology in maintaining and controlling the quality of pond water and promoting the efficient farm management [3]-[7]. However, these works only focus their attention on the design of a smart aquaculture system based on wireless sensor network technology, not the study of the efficiency that the farmer actually gains from utilizing their systems. Unlike the previous works, our study aims to investigate the significance of efficiency improvement obtained from adopting wireless sensor technology over the use of a traditional approach in an integrated giant freshwater-white prawn culture, hoping to promote the use of this smart farming approach among Thai farmers.

The rest of this paper is organized as follows. Section II-A presents the design of a smart prawn farming that is used to carried out the study of the efficiency improvement. The experiment setup and results are illustrated and discussed in Section III. Finally, we conclude our work in Section IV.

## II. Smart Prawn Farming Design

### A. Overview of the System

A sensor node, used in this study, is designed to be able to well adjust and adapt to achieve greater farm efficiency in terms of both the time consumption spent on managing the farm and the productivity. As such, there are two subsystems integrated inside each node: (1) a water quality monitoring and controlling subsystem and (2) an automatic feeder subsystem. The water quality monitoring and controlling subsystem constantly monitors essential factors that are used to indicate the water quality (e.g., dissolved oxygen (DO) and pH and temperature), as shown in Fig 1. Data taken from this subsystem are then used in determining whether it is time to activate an aerator and a food feeder subsystem.

An automatic feeder subsystem is designed to help the farmers to alleviate the tedious and time-consuming tasks such as daily feeding and calculating the right amount of each feed, according to the number and the age of the prawns inside the pond. By doing so, increasing the number of daily feed, instead of a manual feed in traditional farming that can only be done typically twice a day, can be done with ease. This consequently leads to efficiency arising from being able to reduce the demand of manpower and increase the growth rate of prawns. In order to work as desired, the subsystem accepts a set of data such as the time, the amount of food as well as the age and the total number of prawns residing in the pond, from a farm manager through a GUI interface. With these data together with our developed software, the subsystem determines a daily feeding pattern which includes the amount and the duration of each feed and the total number of feeds daily. The system integrates this daily feeding pattern with a current water quality level, obtained from the water monitoring and controlling subsystem, to automatically activate the feeder.

The data (DO, pH and temperature and water quality level, the time and duration of feed and the amount of feed) are constantly transmitted from the sensor node to the gateway, via an X-bee module that is equipped at both a sensor node and a gateway (see Fig. 2). These data are then saved into a log file at the server which can later be retrieved by a farm manager for further usage (e.g. generating a report and analyzing the previous culture period's log for better productivity in the next round). Also, our smart farming system is able to perform a real-time communication with a farm manager through an SMS module that is equipped at the server. This serves as an alert when a predefined critical event is triggered.

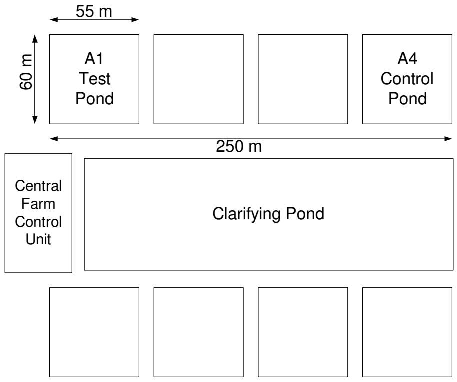
### B. Details of the System

*1) Sensors:* Since DO, pH and temperature are key factors in determining the quality of water for aquaculture, we use 3 types of digital sensors to sense pond water for these key parameters. The temperature sensor used in this project is DS18b20 which can measure the temperature within a range of -55-125 °C with the accuracy of 12 bits or 0.0625 °C. Besides its wide available reading temperature range, DS18b20 is also inexpensive and has a plastic cover which makes it suitable for our application.

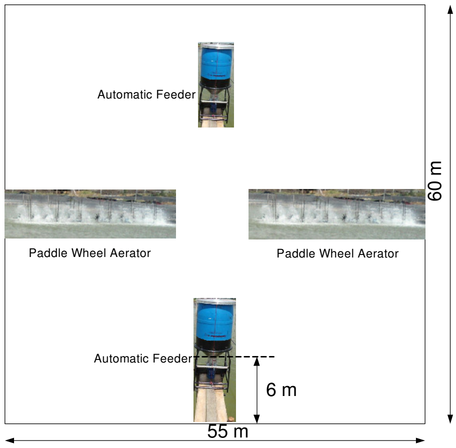
pH and DO sensors, each comes with its own processing unit (shown in Fig. 3), are from Atlas Scienctific Biology Technology which can measure pH and DO within the ranges of 0-14 and 1-20 ppm, respectively. These sensors are able to

Fig. 3. pH and DO sensors, mounted in an IP 65 housing,with their own processing units.

Fig. 4. The processing system of a sensor node.




(a) Layout of the entire farm showing the dimension of both the test and the control ponds.




(b) Two paddle wheel aerators and two automatic feeders are installed in both the test and the control ponds

Fig. 5. Experiment Setup

work continuously[1] without the need to clean and recalibrate the sensors every time after each use.

*2) Processing Unit:* The processing unit (shown in Fig. 4) is composed of an X86 processor with the model number of VSX-6154-V2/ VSX-6154-V2-PLUS. Although it is quite pricy (e.g. 180 $USD), this processor is chosen because of its potentials in computational speed, stability, low power consumption, as well as various available I/O ports (e.g., GPIO, RS232, RS485 and LAN). In our design, the sensor node not only sense and transmit the sensed data to the gateway, but also analyzes the data obtained from the sensors for further actions. Note that the data sent to the gateway is only for logging and reporting purposes as well as providing a communication through GSM and the Internet networks. With this design, the farmers may control the farm management system from a central farm control unit or at the sensor node itself.

*3) Communication Subsystem:* The communication system is divided into short-ranged and long-ranged communications. Short-ranged communication (range $\leq$ 250 m) is used for sending data between a sensor node and a gateway, located at the central farm control unit. This is possible wirelessly by using an X-bee Pro 802.15.4 module that utilizes ZigBee protocol. The gateway is connected to the server which is responsible for long-ranged communication. Specifically, long-ranged communication can be done using a GSM module SIM300CZ to connect to the GSM network. This serves as to notify the farm manager about the current status of the farm or when a predefined event has been triggered, via an SMS. Another way of long-ranged communication is through the LAN interface of the server. This allows the farm manager to access for monitoring and controlling the farm via the Internet.

## III. Experiment Setup and Results

### A. Experiment Setup

In order to obtain the performance improvement between prawn culture with the traditional and the smart farming approaches, we conduct an experiment of prawn culture using two earthen ponds, one being as a test pond (refers to pond A1) and another one being as a control pond (refers to pond A4), as shown in Fig 5(a). Both ponds have the same dimension

[1]Although these sensors can perform pH and DO measurement continuously, after a period of time, e.g. say 3 weeks, they still need to be cleaned and recalibrated. However, the length of a period without maintenance depends greatly on the cleanliness of the sensor. For our project, maintenance of the sensors is carried out approximately every 3 weeks.

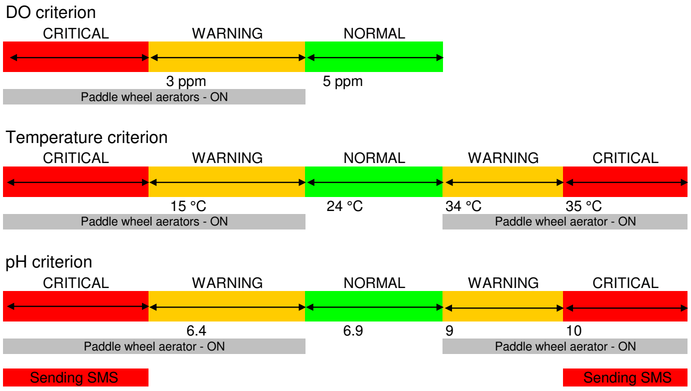



Fig. 6. Predefined criterion for decision making in activating the paddle wheel aerators and the SMS sending module.

of 55 m x 60 m x 3 m and are filled with water of 2-meter depth. There is a central farm control station in which the main server and the farm manager reside. This station is away from pond A1 and pond A4 approximately 53 m and 270 m, respectively. The sensors are placed at the water level of 30 cm above the bottom of the pond. In each pond, there are two sets of paddle wheel aerators and a water quality monitoring system installed. For the test pond, we also install two automatic feeders at the position shown in Fig. 5(b).

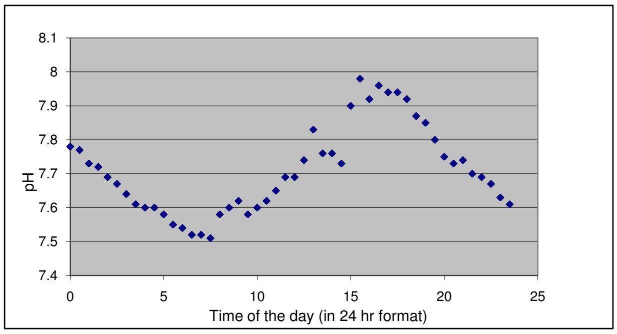
The criterion for activating and deactivating the aerators for the test and the control ponds are slightly different. Specifically, for the control pond which applies a traditional farming approach, the aerators will be activated daily according to the default predefined sets of time and duration which are 10.00-11.30, 14.30-16.30 and 21.00-06.30, if not specified otherwise. For the test pond, the default time and duration pattern is applied and the time of the day during which is not specified within the default pattern, addition criterion, as shown in Fig. 6, applies. For example, if the system detects that the DO is being less than 5 ppm (look at DO criterion, water quality level is WARNING when DO drops below 5 ppm), the aerator will automatically be activated even if the current time is not belong in the set of predefined time. Whenever the quality level of the test pond water changes to CRITICAL, besides of having the aerators activated, the SMS module will promptly send an SMS to alert the farm manager about the critical event. The experiment is carried during Dec 2013 - March 2014 and the number of the breed of Macrobrachium Rosenbergii and white prawn in both ponds are 100,000 and 150,000, respectively, per pond.

### B. *Results*

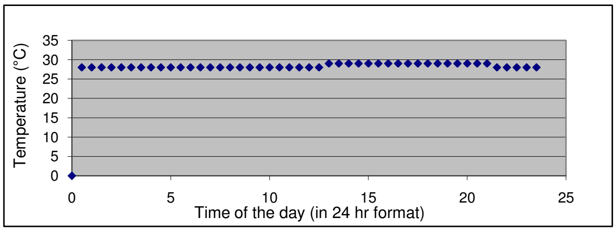
Fig. 7(a) - Fig. 7(c) show the data[2] collected from the pH, DO and temperature sensors, respectively, for one particular day. pH and temperature do not fluctuate much during the day as they range from 7.5-8 and 27-29.8 °C, respectively. DO level is quite low (below 5 ppm) after midnight til 11.00, indicating that this is the period that needs attention. Among the three monitored factors, DO is the only factor that causes water quality level to be WARNING status. According to the data, only between 00.00-11.00 that DO drops below 5 ppm, leading to the need to activate the aerators. The main reason causing the DO drops during the night time is that there is no photosynthesis. We also witness that during the day whereby photosynthesis takes place, the level of DO constantly increases between 08.00-16.30 and after that DO drops again.

Comparing to the default timing pattern used in activating an aerator for traditional approach, we see that the aerators are over-activated during 11.00-11.30, 14.30-16.30 and 21.00-23.59, for the total of 6.5 hrs for this particular day. By

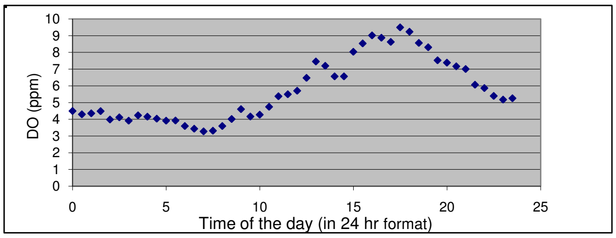
[2]These data are obtained on the 41$^{st}$ day after the culture has started.




(a) pH sensor data.




(b) Temperature sensor data.




(c) DO sensor data.

Fig. 7. An example of the results obtained from pH, temperature and DO sensor within a particular day during the culture period.

TABLE I
DATA ON TOTAL COST, PRODUCTIVITY AND TOTAL INCOME OBTAINED FROM TEST AND CONTROL PONDS

| Factors | Test Pond (A1) | Control Pond (A4) |
|---|---|---|
| Culture Period (days) | 89 | 74 |
| Total Cost ($) | 3,968 | 3,137 |
| Macrobrachium Rosenbergii (Kg) Production | 283 | 260 |
| White prawn Production (Kg) | 990 | 620 |
| Total Income ($) | 9,871 | 5,491 |

using the smart farming approach, it is obvious that this over-activated period can be eliminated, resulting in lower electrical consumption. From our recorded data during the whole culture period of 89 days (see Table I), it is important to note that although the trend of DO exhibits similar pattern periodically with the period of 24 hours, the duration in which the DO drops to WARNING level varies according to multiple factors. For example, during the first 50 days of prawn culture, there is no need to activate the aerators during other period except between 00.00-11.00, as shown in Fig. 7(c) . However, it is noticed (results not shown here) that as the number of days after the culture has started increases, the duration of aerator activation, due to the drop of DO below 5 ppm, also increases. After 75 days of prawn culture, DO drops to WARNING not only during the night but also during the day, resulting in the need of aerator activation of almost 20 hours/day. When 85 days have passed, the aerator activation due to the drop of DO is even worse, such that even aerator activation cannot increases the DO level to be higher than 5 ppm, resulting in 24 hours/day of aerator activation.

Table I presents the results from both the test and control ponds, in terms of culture period, total cost, productivity and total income. The culture period of the test and the control ponds are 89 and 74 days, respectively. The main reason of this significant difference arises from the fact that the aerator activation algorithm implemented for control pond is statically defined only once, when the culture starts, by activating the aerator distributively throughput the 24-hour period. As indicated earlier that after 75 days of prawn culture, the water quality always drops from NORMAL to WARNING and requires the activation of the aerators. However, for the control pond, since the aerators only activate on the predefined set of time and hence no activation of the aerators for certain duration of the time. This consequently leads to the CRITICAL level of water quality and eventually the dead of prawns only after 74 days after the culture has started. On the other hand, the aerator activation algorithm in the test pond also takes the water quality level into consideration. As a result, it is able to extend the culture period to 89 days.

The total cost[3] of the test and the control ponds are $3,968 and $3,137, respectively. Although the total cost of the test pond seems to be much higher than the control pond, the productivity and the total profit from the test pond are significant higher due to the 15-day longer culture period. For more detail, the profit from the test pond is over 150%[4] higher than from the control pond.

## IV. Conclusions

In this paper, a study of an efficiency improvement from applying a smart farming approach over a traditional approach, in an integrated giant freshwater-white prawn culture in Thailand, has been conducted. The smart farming approach utilizes a wireless sensor network technology, in order to achieve significant efficiency improvement. Specifically, there are two subsystems integrated inside each sensor node: (1) a water quality monitoring and controlling subsystem and (2) an automatic feeder subsystem. The water quality monitoring and controlling subsystem constantly monitors essential factors that are used to indicate the water quality (e.g., dissolved oxygen (DO) and pH and temperature). Data taken from this subsystem are then used in determining whether it is time to activate an aerator and a food feeder subsystem. Experimental results show that, with this approach, significant efficiency gain can be achieved from the ability to extend the culture period significantly by 20.3%, leading to larger-size prawns and more than 150% better in profit.

As the results presented in this paper is only preliminary work based on an experiment of a single culture period that is conducted between Dec 2013-Mar 2014, it is interesting to investigate further whether there is any significant difference in terms of DO, pH and temperature variations for other period of the year. The obtained data can then be accurately formed an optimal year-round prawn culturing program. Moreover, integrating more sensors in the proposed water monitoring system, in order to be able to real-timely monitor other useful parameters such as nitrate and ammonia levels, can also be one of the future research direction. This is because nitrate and ammonia levels also significantly affect the health of prawn as well.

## Acknowledgment

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[3]This includes the cost of the breed of prawns, food, medicine vitamin and chemical substances, wage and electrical charge.

[4]The profit is calculated based on the actual profit gained by the farmers.